CM613 Week 6 Seminar exercises

1. My old SoundBlaster card is an 8-bit sound card.

   (a) What is it 8 bits of?

   (b) What is the best SQNR it can achieve?

2. If a set of ear protectors reduces the noise level by 30dB, how much do they reduce the intensity (power) by?

3. Suppose the sampling frequency f_s is 1.5 times the true frequency f_t. What is the alias frequency f_a?

4. Suppose a signal contains tones at 1, 10, and 21kHz and is sampled at the rate 12kHz (and then processed with an antialiasing filter limiting output to 6kHz). What tones are included in the output? *Hint: most of the output consists of aliasing.*

   Note for Q3 & Q4

   If $f_s < 2f_t$ and $f_s > f_t$ then
   $f_a = f_s - f_t$
   If $f_s < f_t$ then
   $f_a = (n \times f_s) - f_t$ where n is the lowest integer that makes $n \times f_s > f_t$

5. The dynamic range of a signal *V* is the ratio of the maximum to the minimum absolute value expressed in decibels. The dynamic range expected in a signal is to some extent an expression of the signal quality. It also dictates the number of bits per sample needed to reduce the noise to at least an order of magnitude below V_{min}. Suppose the dynamic range for a signal is 60dB. Can we use 10 bits for this signal? Can we use 16 bits?

   Notes for Q5

   Quantization interval *q* is given by:
   $$q = \frac{2 \times V_{max}}{2^N}$$

   Quantization noise is half the quantization interval:
   $$\frac{V_{max}}{2^N}$$

   The dynamic range is V_{max}/V_{min}, where V_{min} is the smallest positive voltage we can see that is not masked by the noise. Since the dynamic range is 60 dB, we have
   $$20 \times \log_{10}\left(\frac{V_{max}}{V_{min}}\right) = 60 \text{ dB}$$

   which means we can calculate V_{min} as $V_{max}/1000$, because
   $$20 \times \log_{10}(1000) = 60$$
   $$\log_{10}(1000) = 3$$

So, you can calculate V_{min} for 10 bits, and then for 16 bits. (Answers at end).

6. Draw a diagram showing a sinusoid at 5.5kHz and sampling at 8kHz (show eight intervals between samples in your plot). Draw the alias at 2.5kHz and show that in the eight sample intervals, exactly 5.5 cycles of the true signal fit into 2.5 cycles of the alias signal.

Answers

1. Soundblaster card is:
    a. 8 bits of sampling resolution or **quantization levels**
    b.
$$\begin{aligned} SQNR &= 20 \times N \times \log_{10}(2) \\ &= 20 \times 8 \times 0.301029995664 \\ &= 48.16 \end{aligned}$$
2. 1000 times
3.
$$\text{If } f_s < 2f_t \text{ and } f_s > f_t \text{ then}$$
$$\begin{aligned} f_a &= f_s - f_t \\ &= 1.5f_t - f_t \\ &= 0.5f_t \text{ or } \frac{f_t}{2} \end{aligned}$$
4.
$$1 \text{ KHz}, 12 - 10 \text{ KHz}, \text{ and } (2 \times 12) - 21 = 3 \text{ KHz}$$
5. At 10 bits the quantization noise is
$$q = \frac{V_{max}}{2^{10}}$$
$$= \frac{V_{max}}{1024}$$
which is not 1 order of magnitude smaller than the original Vmin, so 10 bits is not enough. However, 16 bits gives us
$$q = \frac{V_{max}}{2^6 \times 2^{10}} \text{ n.b, same as } 2^{16}$$
$$= \frac{V_{max}}{64 \times 1024}$$
which is way more than 1 order of magnitude less.